VARIABLE IMPEDANCE MATCHING CIRCUIT

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to an impedance matching circuit of a radio frequency circuit, in particular, to a variable impedance matching circuit capable of variably matching RF impedances in accordance with control signals.

DESCRIPTION OF THE PRIOR ART

In a radio frequency circuit, the matching circuit acts to transmit signals from one unit block to other one without an echo back (reflection of incident signal.) The conventional methods for implementing such a matching circuit have been disclosed. One of them is a method of using micro-strip lines and stubs, another is a method of implementing the matching π or L type circuit using lumped elements: capacitances, inductances.

The former has used micro-strip lines and stubs at fixed electrical lengths, and the latter has been implemented the matching circuit with fixed topology using inductance and capacitance; the matching circuit could not be changed once it has been implemented.

Thereafter, the impedance matching circuit implemented using the stubs will be explained with reference to Fig. 1. In this prior art, in order to match required impedances, a matching circuit network is used which comprises a transmission line having characteristic impedances and a stub

parallely or serially connected thereto.

Fig. 1 shows the matching circuit network using stubs connected in parallel with each other. Referring to Fig. 1, a required real part of the impedance is obtained by varying the length **11** of the transmission line **L11** having a characteristic impedance, and a required reactance value is obtained by adjusting the length **12** of the stub **L12** connected in parallel to the transmission line **L11**. In this case, a matching circuit is designed by varying the length **L11** of the transmission line **L11** having the characteristic impedance and the length **12** of the stub as design parameters of a required matching circuit network. Such matching method using the stub is commonly used in the microwave frequency range.

Meanwhile, the matching circuit network can be implemented by using lumped-element inductance and capacitance. This matching circuit network can be implemented by using a π or L type circuit network in order to match the required impedance value. Two lumped elements are used for the L type circuit network as a design parameter, and a topology is determined by which side of the two lumped elements is grounded. And values of the two lumped elements are used for the design parameter. Also, three lumped elements are used for the π type circuit network, and a topology is determined by that which side of the three elements is grounded, and values of the three lumped elements are used for the design parameter.

Therefore, the matching methods using the stub and the lumped elements of the prior art can not vary the matching circuit after the matching circuit has been implemented as a hybrid or an integrated circuit.

SUMMARY OF THE INVENTION

Therefore, one object of the present invention is to provide a variable impedance matching circuit capable of matching impedances by varying the electrical lengths of the transmission lines, with control signal operations of switches.

The other object of the present invention is to provide a variable impedance matching circuit capable of matching impedances by changing a topology of matching circuit or by changing values of the variable inductance or variable capacitance, with operations of the switch used in accordance with control signals.

To achieve the above objects, the variable impedance matching circuit in accordance with the present invention comprises at least one stub lines connected in parallel or serial to a transmission line. It is characterized in that the at least one stub lines and transmission line comprises at least one variable transmission line block which changes its electrical length using at least one of external signal(s) controlled switches.

To achieve the above objects, in a π type variable impedance matching circuit in accordance with the present invention, a first, a second, and a third lumped element connected with a shape of π type and at least one of switches, which are capable of being operated by external control signals, are connected to connection point(s) of lumped elements, wherein a topology is changed by selecting input/output ports or grounds using at least one of switches.

To achieve the above objects, in a L type variable impedance

matching circuit using lumped elements in accordance with the present invention, first and second lumped elements are connected with a shape of L type and at least one of switches, which are capable of being operated by external control signals, are connected to connection point(s) of said lumped elements, wherein a topology is changed by selecting input/output ports or grounds using said at least one of switches.

The present invention relates to a variable impedance matching circuit capable of performing impedance match. The variable impedance matching circuit in accordance with the present invention has given impedance corresponding to a control signal by the external control signal in a radio frequency range. In other words, in the matching circuit using stubs, the variable impedance matching circuit is implemented by varying the electrical length of the conventional transmission line by means of the external control signal. And in the L or π type matching circuit using inductances and capacitances as lumped elements, the variable impedance matching circuit is implemented by changing the topology of the circuit network by means of the external control signals, or by having variable inductances or variable capacitances capable of being controlled as lumped elements thereby changing impedances thereof. When it comes to implement the variable impedance matching circuit using lumped elements, a topology of the matching circuit first needs to be selected by switches. As each component of the topology consists of the variable inductance or variable capacitance, a required impedance matching circuit can be implemented by changing values of the variable inductance and variable capacitance. Therefore, it is possible to

control impedances from any ones to the ones to be matched by using the variable impedance matching circuit in accordance with the present invention. In addition, a radio frequency circuit to which the variable impedance matching circuit belongs can be controlled, thereby a matching circuit can be implemented from an arbitrary RF signal source to an arbitrary complex load.

Hereinafter, embodiments of the present invention will be explained with reference to the accompanying drawings. Although the present invention has been described in conjunction with the preferred embodiment, the present invention is not limited to the embodiments, and it will be apparent to those skilled in the art that the present invention can be modified in variation within the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a matching circuit network using parallel connected stubs.

Fig. 2 shows transmission lines capable of varying electrical lengths.

Fig. 3 shows a variable impedance matching circuit using stubs by connecting the variable transmission lines shown in Fig. 2.

Fig. 4 shows a variable impedance matching circuit using two stubs by connecting the variable transmission lines in parallel shown in Fig. 2.

Fig. 5 shows a π type variable impedance matching circuit.

Fig. 6 shows a L type variable impedance matching circuit.

Fig. 7 shows one embodiment in which the variable impedance matching circuit according to the present invention is applied to a radio

frequency circuit.

Fig. 8 shows another embodiment in which the variable impedance matching circuit according to the present invention is applied to another radio frequency circuit.

DESCRIPTION OF THE PREPERRED EMBODIMENTS

Fig. 2 shows transmission lines capable of varying electrical lengths. Referring to Fig. 2, the transmission lines can vary electrical lengths by changing the electrical paths of radio frequency signals by means of switches. Typically, a micro-strip line, which is a transmission line, formed on a substrate can have a predetermined thickness as shown in Fig. 2, and the electrical characteristic thereof can be changed in accordance with the width. The circuit as shown in Fig. 2 acts as a phase shifter in view of a fixed frequency. The transmission lines, capable of varying electrical lengths shown in Fig. 2, comprise 1 to N variable transmission line blocks. A first variable transmission line block **B21** comprises switches **SW21**, **SW22**, and a transmission line **L21**. The switches **SW21 and SW22** can be implemented as MOS transistors or PIN diodes which can function as switch, and the transmission line **L21** has an electrical length θ 21. Other variable transmission line blocks **B22, B23,..., B2N,** having same structures as that of the first variable transmission line block **B21,** are consecutively connected, thereby a total variable transmission line are obtained. The nth transmission line L2N of the variable transmission line blocks has an electrical length θ 2N. Variable range of the θ **2N** needs to have the value that the difference

between the maximum and the minimum lengths is not less than $1/2\lambda$. Therefore, the sum (Σ B2N) of variable length blocks is not less than $1/2\lambda$. For example, method in which unit block (L = $1/2\lambda$)/N (wherein the N is a number of unit block) length is the same, has the transmission line length (N* Θ ,wherein the Θ is the length of unit block) by connecting N of unit block each other by means of the switches of the unit block. As a alternative, the length of the transmission line can be a different each of unit block; for example, the transmission line can be implemented having N of unit block comprising the longest transmission line of $1/4\lambda$, and the shortest transmission line of $1/(2*(N+1))\lambda$ in length. Therefore, the transmission line can be varied so that the electrical length thereof has resolution of $1/(2*(N+1))$multiplied by $1/2\lambda$.

The operation of the first variable transmission line block **B21** will be explained hereinafter. The transmission line **L21** having electrical length Θ 21 can be selected by using switches **21 and 22.** In other words, when the switch **SW21** is turned on and switch **SW22** is turned off, an input signal input from the Port **21** flows through the **L21**. Therefore, the input signal flows through the transmission line that has long electrical length. On the other side, when the switch **SW21** is turned off and switch **SW22** is turned on, the input signal directly flows without through the **L21** so that the electrical length of the transmission line can be varied depending on the operation of the switches **SW21 and SW22.** The electrical length of the total variable transmission line consisting of 1 to N variable transmission line blocks can be varied by the combination of switches for each block for cases up to 2^N. In

addition, the variable transmission line shown in Fig. 2 acts as a phase shifter, so that the phase displacement can be changed to θ 21, θ 22,.., θ N by selecting the switches.

Hereinafter, the variable impedance matching circuit implemented using the variable transmission line shown in Fig. 2 will be explained with reference to Fig. 3 and 4.

Fig. 3 shows the variable impedance matching circuit using stubs by connecting the variable transmission lines shown in Fig. 2. As explained above with reference to Fig. 1, the matching circuit using stubs consists of a transmission line part **31** and a stub line part **32** connected in parallel or serial to the transmission line. The variable impedance matching circuit can be implemented as shown in Fig. 3. Referring to Fig. 3, the variable impedance matching circuit consists of a transmission line part **31** and a variable length stub line part **32**. First variable transmission line block of the transmission line **L31** consists of a switch **SW31**, switch **SW32**, and a transmission line **L31**. Other blocks of the transmission line also consist of switches and a transmission respectively, so that the electrical length of the total transmission lines is varied. And the first transmission line variable block of the variable length stub line **L32** also consists of a switch **SW33**, a switch **SW34**, and a transmission line **L32**, so that the electrical length of the total stub lines are varied by the operation of each transmission line variable lock. Signals are input from Port 31 and output to Port 32.

Fig. 4 shows a variable impedance matching circuit connecting two stubs in parallel to the variable transmission lines, respectively, as shown in

Fig. 2. Referring to Fig. 4, the variable impedance matching circuit using two stubs in Fig. 4 consists of a first variable length stub line part **41**, a second variable length stub line **42,** and a transmission line to which the first variable length stub line part **41** and the second variable length stub line part **42** are connected at both ends thereof. The transmission line has an input Port 41 and an output Port 42. The first variable length stub line part **41** consists of plurality of variable transmission line blocks, and the first block thereof consists of a switch **SW41**, a switch **SW42**, and a transmission line **L41**. In addition, the second variable length stub line part **42** consists of plurality of variable transmission line blocks, and the first block thereof consists of a switch **SW43**, a switch **SW44**, and a transmission line **L42**. The electrical length of each variable transmission line block is varied depending on the operation of switches. In the case of typical double stub matching as shown in Fig. 4, the length of the transmission line is fixed (to $1/8\lambda$ or $1/4\lambda$), thereby the matching circuit can be implemented by varying the lengths of the two stubs in accordance with the required impedance.

Hereinafter, π or L type variable impedance matching circuit using inductance and capacitance as lumped elements will be explained with reference to Fig. 5A, 5B, 6A and 6B.

Fig. 5A and 5B show π type variable impedance matching circuits. Referring to Fig. 5A, the variable capacitance and inductance are connected with a π shape. For example, the numerical references **e51, e52, and e53** each can correspond to the variable capacitances or the variable inductances. Switches **SW51 and SW52** are connected to the left side of **e51**, and the

switch **SW51** is connected to ground level **GND51**, and the switch **SW52** to Port51. In addition, Switches **SW53 and SW54** are connected to the right side of e51, and the switch **SW53** is connected to ground level **GND52**, and the switch **SW54** to Port 52. One ends of e52 and e53 are connected to e51, and the other ends thereof are connected to Switches **SW55 and SW56**, respectively.

Fig. 5B shows the π type impedance matching circuit implemented by the principle referring to Fig. 5A, and will be explained in accordance with the operation of Fig. 5A. When switch **SW51** is turned on and switch **SW52** off in Fig. 5A, then Port 51 is activated. When switch **SW53** is turned off and switch **SW54** on, the Port 52 is activated. And when the switch **SW56** and turned off and switch **SW55** on, the structure can be obtained in Fig. 5B by having one terminal of e53 and e52 grounded. By means of the switch control explained above, the variable inductance or the variable capacitance e51 can be positioned between input Port 51 and out Port 52, and e52 and e53 can be connected to the both terminals of e51.

Fig. 6A and 6B shows the L type variable impedance matching circuit. Referring to Fig. 6A, the variable capacitance and inductance are connected with a L shape. For example, the numerical references e61 and e62 each can correspond to the variable capacitances or the variable inductances. The terminals of e61 and e62 are connected each other, thereby connected to Port 62, and the other terminals are connected to switches. For example, the other terminal of e61 is connected to switches **SW61 and SW62**, and switch **SW61** is connected to ground level **GND61**, and switch **SW62** to Port 61. The

other terminal of e62 is connected to switches **SW63 and SW64**, and the switch **SW63** is connected to ground level **GND62**, and the switch **SW64** to Port 63.

Fig. 6B shows the L type impedance matching circuit implemented by the principle referring to Fig. 6A, and will be explained in accordance with the operation of Fig. 6A. When the switch **SW61** is turned off and the switch **SW62** on in Fig. 6A, then Port 61 is activated. And when the switch **SW64** is turned off and the switch **SW63** on, the structure shown in Fig. 6B can be obtained by having one terminal of e62 grounded.

Hereinafter, the embodiment in which the variable impedance matching circuit according to the preferred embodiment of the present invention is applied to a radio frequency circuit will be explained with reference to Fig. 7 and 8.

Fig. 7 shows one embodiment in which the variable impedance matching circuit according to the present invention is applied to a radio frequency circuit. The radio frequency circuit shown in Fig. 7 consists of a RF signal source **70**, a first variable impedance matching circuit **71**, a RF device **72**, a second variable impedance matching circuit **73**, and a load **74**. First and second external control signals **75 and 76** are input to the first and second variable impedance matching circuits **71 and 72**, respectively. The value of input impedance of the RF device **72** is different from that of output impedance of the RF signal source **70**. Therefore, the impedances of the RF device **72** and RF signal source **70** need to be matched each other for the purpose of signal transmission without an echo back. And, the output of the

RF device **72** should also be matched to the impedance of the load **74** to which the output be transmitted. At this time, as the input and output impedances of the RF device **72** are fixed, input and output of the RF device can be adjusted to arbitrary values by the variable impedance matching circuit in accordance with the present invention. For example, the first variable impedance matching circuit is connected between the RF signal source **70** and the RF device **71**, and the second variable impedance matching circuit is connected between the RF device **72** and the load **74**. Therefore, the RF device can be connected to the RF signal source as an input and to the load as an output, and then used.

Fig. 8 shows another embodiment in which the variable impedance matching circuit according to the present invention is applied to another radio frequency circuit. The radio frequency circuit shown in Fig. 8 consists of a RF signal source **80**, a variable impedance matching circuit **81**, a time variable complex load **82**, and a control part **83**. The radio frequency signal is transmitted from the RF signal source **80** to the time variable impedance matching circuit **81** by using the variable impedance matching circuit in accordance with the present invention. Referring to Fig. 8, the value of impedance of the time variable impedance matching circuit **81** is different from that of the RF signal source **80**, and the value of impedance of the time variable complex load **82** varies as time proceeds. The output signal of the time variable complex load **82** is input to the control part **83**, which in turn generates a control signal and input the control signal to the variable impedance matching circuit **81**. Therefore, the variable impedance matching

circuit **81** performs impedance matching between the RF signal source **80** and the variable complex load **82**.

As explained above, the variable impedance matching circuit according to the present invention, varies the electrical lengths of transmission lines, changes the topology of the variable inductance or variable capacitance as lumped elements, or varies the values of the variable inductance or variable capacitance by using the operation of switches in accordance with the control signal, thereby adaptive impedance matching can be performed to an arbitrary RF circuit. In particular, when the load to which the RF signal is transmitted varies as time proceeds, matching can be performed in accordance with the variable load, and digital control is available, thereby the RF related signal or device could be digitally controlled.

Although the present invention has been described in conjunction with the preferred embodiment, the present invention is not limited to the embodiments, and it will be apparent to those skilled in the art that the present invention can be modified in variation within the scope of the invention.